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- Schemenner, R.W., Huber, J.C. and Cook, R.L. (1987), "Geographic Differences and the Location of New Manufacturing Facilities," Journal of Urban Economics, Vol. 21, No. 1, pp. 83-104.

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PERFORMANCE EVALUATION AND ENHANCEMENT OF THE INITIAL RANGING MECHANISM IN MAC 802.16 FOR WIMAX NETWORKS USING NS-2

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ABSTRACT

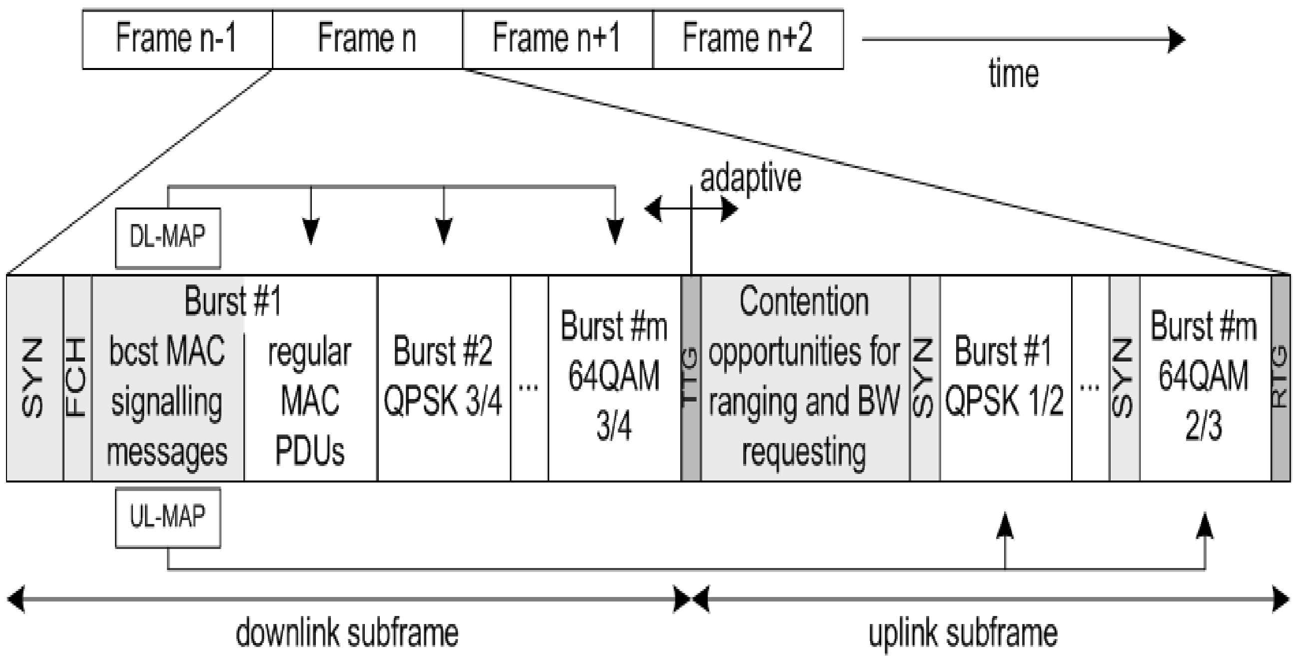
In the IEEE 802.16 standard, Initial Ranging (IR) is defined as the mechanism of acquiring the correct timing offsets and power adjustments such that the Subscriber Station (SS) is co-located with the Base Station (BS). In this paper, we evaluate the performance of this mechanism based on the metrics of delay and success-ratio. First we analyze IR using a Markov Model and arrive at an expression for the delay incurred. Next we enhance its performance by introducing a novel principle of circularity. Circularity is a paradigm that allows the identification of specific groups of packets or events. Employing this principle, we introduce delay control and backoff window control into IR. This new paradigm reduces the collisions among request packets and thereby, reduces the delay resulting in the increase of the success-ratio of IR. The evaluation and enhancement are performed through extensive simulation studies using NS-2.

KEYWORDS
WiMAX, MAC 802.16, Network Entry Process, Initial Ranging, Contention Resolution, Circularity.

INTRODUCTION
The IEEE 802.16 standard for Wireless Metropolitan Area Networks currently presents the most recent development of wireless technology. It was originally intended for Fixed Broadband Wireless Access (FBWA) networks and as a wireless competitor for wireline DSL and cable modem access in particular in rural and low-infrastructure areas. The most recent stage of the IEEE 802.16 standard also provides mobility support mainly intended for nomadic users or users with little mobility. Worldwide Interoperability for Microwave Access (WiMAX) is a consortium founded to enable the interoperability and foster the commercialization of products based on the IEEE 802.16 standard. The current IEEE 802.16-2004 standard with the extensions for mobility support amended in the IEEE 802.16e-2005 standard is the basis for the two classes of WiMAX certified products. The Orthogonal Frequency Division Multiplexing (OFDM) part of IEEE 802.16-2004 is called Fixed WiMAX and the Orthogonal Frequency Division Multiple Access (OFDMA) part of IEEE 802.16e-2005 is called Mobile WiMAX.

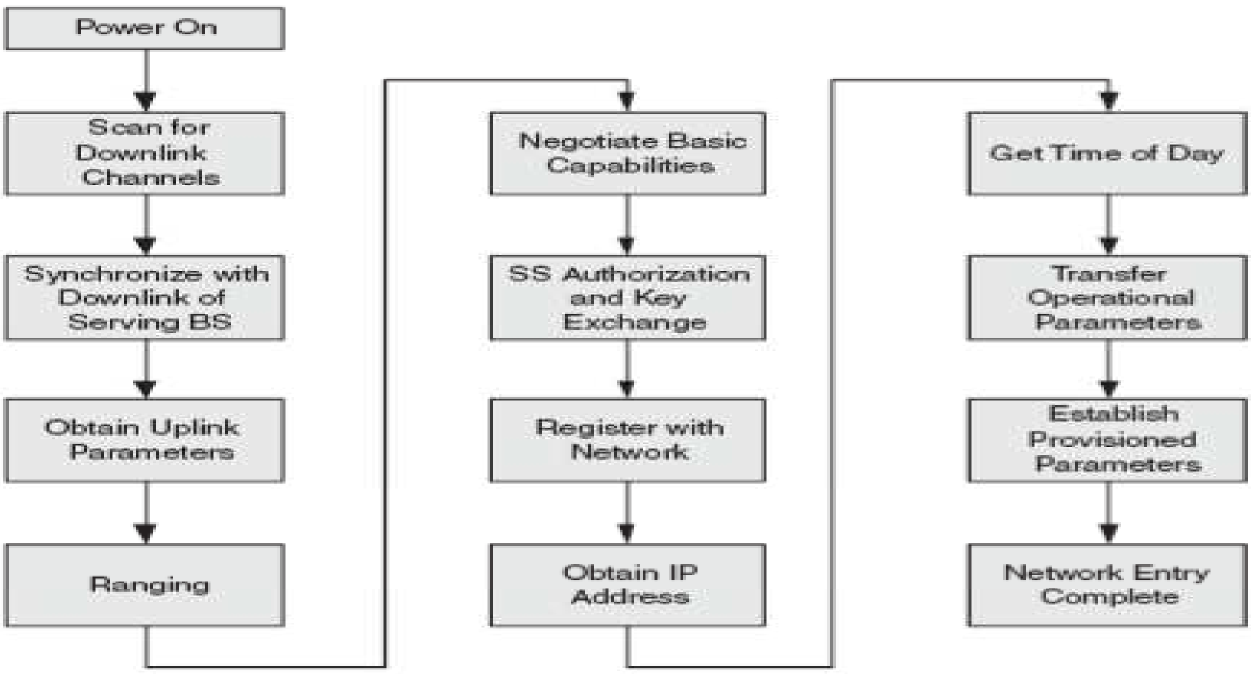
At the physical layer defined by the IEEE 802.16 standard, the flow of bits is structured as a sequence of frames of equal length. There is a downlink subframe and an uplink subframe in the Time Division Duplexing (TDD) mode of operation, and they are consecutive. In TDD, the portion allocated for the downlink and portion allocated to the uplink may vary. Downlink map (DL-MAP) and uplink map (UL-MAP) signaling messages are used to inform SSs about bandwidth allocations in downlink (DL) and uplink (UL) respectively. These are sent on the downlink. The DL subframe also has data bursts addressed to different SSs. The UL subframe begins with contention intervals scheduled for initial ranging (IR) and bandwidth request opportunities. Thereafter the bursts consisting of user data are transferred by particular SSs using different modulation types and coding rates. The Transmit/Receive (Tx/Rx) transition gaps are inserted between the subframes to allow stations to switch between transmission and reception operation modes. The structure is as shown below in Fig. 1.

FIGURE 1: FRAME STRUCTURE FOR IEEE 802.16



NETWORK ENTRY PROCEDURE
A subscriber station (SS) has to complete the network entry process, in order to communicate on the network. The first stage of network entry is Downlink Channel Synchronization. When an SS wants to communicate on a WiMAX network, it first scans for available channels in the defined frequency list. On finding a DL channel, it tries to synchronize at the physical layer (PHY) level using the periodic frame preamble. Information on modulation and other DL and UL parameters is obtained by observing the DL Channel Descriptor (DCD) and the UL channel descriptor (UCD) respectively on the DL channel. In IR, the SS acquires the timing offsets and power adjustments from the BS. This enables the SS to properly communicate with the BS. IR is a very important part of the network entry procedure and is dealt with in more detail in the next section. The network entry procedure is as shown below.

FIGURE 2: NETWORK ENTRY PROCESS



In Exchanging Capabilities, after successful completion of the IR step, the SS sends capability request message indicating the supported modulation level, coding scheme and rates and duplexing methods. In Authentication, the BS authenticates the SS, determines the ciphering algorithm to be used, and sends an authentication response to the SS. In registration, the SS sends a registration request message to the BS and the BS sends a registration response. The registration response message includes the secondary management CID of the SS. Using this, a SS is allowed entry into the network and the SS is said to be manageable. Next in Internet Protocol (IP) Connectivity, the SS gets the IP address via Dynamic Host Configuration Protocol. The SS also downloads other operational parameters using Trivial File Transfer Protocol. In Connection Creation, after completing the IP connectivity step, transport connections are created. For preprovisioned service flows, the BS sends a dynamic service flow addition request message to the SS and SS confirms the creation of connection. For non-preprovisioned service flows, connection creation is initiated by the SS by sending a dynamic service flow addition request message to the BS. The BS responds with the confirmation.

SALIENT FEATURES OF WIMAX

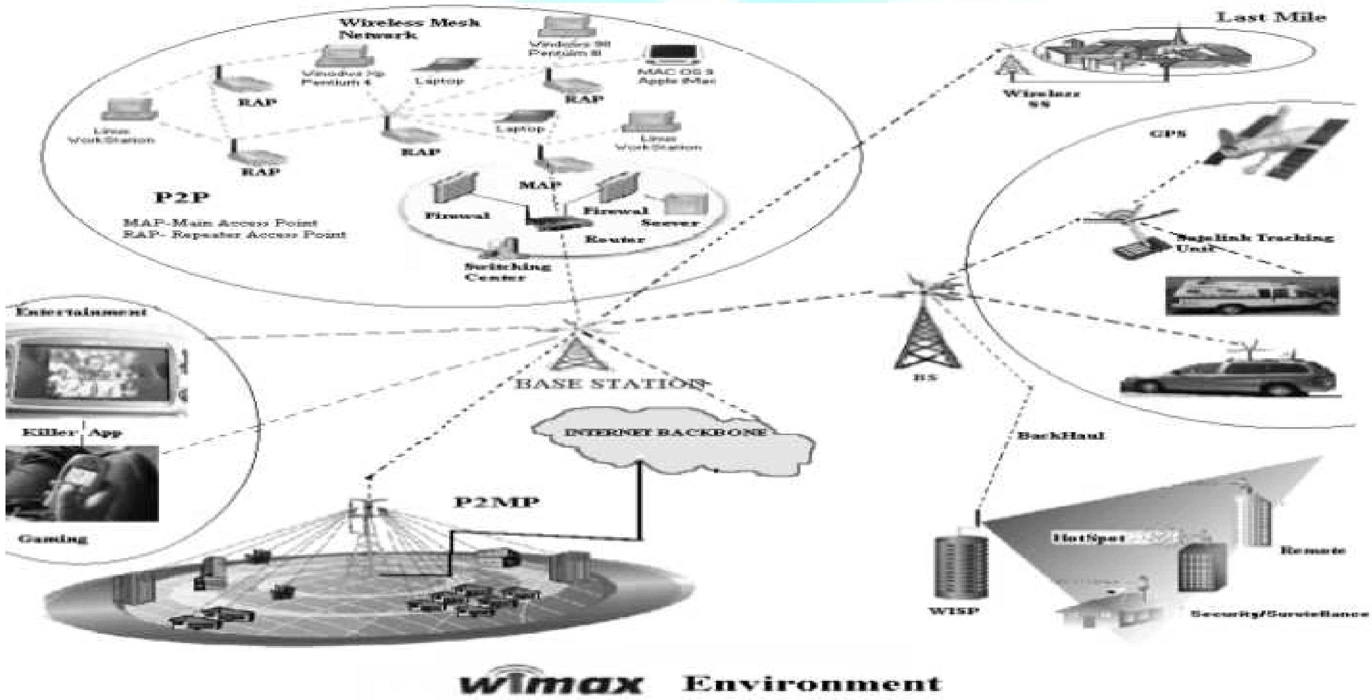
WiMax basically offers two forms of wireless service:

1. **Non-line-of-sight**: This service is a WiFi sort of service. Here a small antenna on your computer connects to the WiMax tower. In this mode, WiMax uses a lower frequency range -- 2 GHz to 11 GHz (similar to WiFi).

2. **Line-of-sight**: In this service, where a fixed dish antenna points straight at the WiMax tower from a rooftop or pole. The line-of-sight connection is stronger and more stable, so it's able to send a lot of data with fewer errors. Line-of-sight transmissions use higher frequencies, with ranges reaching a possible 66 GHz.

The entire WiMax scenario is as shown in **Figure 3.**

FIGURE 3



WiMax is a wireless broadband solution that offers a rich set of features with a lot of flexibility in terms of deployment options and potential service offerings. Some of the more salient features that deserve highlighting are as follows:

- OFDM-based physical layer
- Very high peak data rates
- Scalable bandwidth and data rate support
- Scalable bandwidth and data rate support
- Link-layer retransmissions
- Support for TDD and FDD
- WiMax uses OFDM
- Flexible and dynamic per user resource allocation

INITIAL RANGING MECHANISM

Initial Ranging is an important part of the network entry procedure performed by the SSs, upon power up, in IEEE 802.16 networks. In the IR procedure, the correct timing offsets and power adjustments are obtained from the BS so that the SS can successfully transmit data to the BS. It occurs after the SS has synchronized with a DL channel from the BS and has obtained the UL transmit parameters from the UCD medium access control (MAC) management message. After this the SS will scan the UL-MAP message to find an IR Interval, consisting of one or more transmission opportunities allocated by the BS. The SS begins the IR procedure by assembling a Ranging Request (RNG-REQ) message to be sent to the BS in an IR interval.

The SS sends this message as if it is colocated with the BS. This is done by setting the initial timing offset to the internal fixed delay equivalent to colocating the SS next to the BS. The SS calculates the maximum transmit signal strength for IR and transmits the RNG-REQ message at a power level below this as measured at the antenna connector. In case a response is not received from the BS, the next RNG-REQ message is sent at the next higher power level in the next appropriate IR interval. In case it receives a response from the BS, depending the contents of the response the SS does the following.

If the Ranging Response (RNG-RSP) message contains the frame number in which the RNG-REQ message was sent, the SS will consider the previous attempt to be unsuccessful. Nevertheless, it will make the adjustments specified in the RNG-RSP message. If the RNG-RSP message contains the MAC address of the SS, then the request attempt will be considered successful. When the RNG-REQ message is successfully received by the BS, it will send an RNG-RSP message using the IR Connection Identifier (CID).

At this point the BS starts using Invited Initial Ranging Intervals addressed to the Basic Connection Identifier of the SS to complete the process of IR. But if the status in the RNG-RSP is success, the IR procedure will be completed. On receiving an RNG-RSP message with continue status, the SS first makes the power level and timing adjustments. Then it retransmits another RNG-REQ using the Basic CID assigned to it. The BS yet again sends an RNG-RSP message containing additional fine tuning, if required. This exchange of RNG-REQ and RNG-RSP messages continues till an RNG-RSP message with status success is received by the SS or the BS aborts the IR procedure.

Whenever the SS has to transmit the request packets it performs the Truncated Binary Exponential Backoff procedure. This method is the contention resolution procedure used in IEEE 802.16 networks. The minimum backoff window and the maximum backoff window are both controlled by the BS. Initially the SS sets its backoff window to the minimum possible backoff window. Now the SS randomly selects a number from this backoff window. This number selected indicates the number of IR transmission opportunities that the SS must defer before transmitting the request packet. After the selected number of transmission opportunities is deferred, the SS transmits the RNG-REQ message.

After transmitting the request message, the SS waits for a response message from the BS. If the RNG-RSP message is received from the BS before the specified timeout then the contention resolution is considered to be a success. If not, the SS doubles its backoff window until the maximum backoff window is reached. It then randomly selects another number from this new window and the deferring process is repeated. This may happen due to the collision of RNG-REQ packets or due to the loss of RNG-RSP messages. There exists a maximum limit for the number of such IR retries allowed. If this limit is reached by an SS, then the particular downlink channel being used is marked as unusable and the subscriber station begins scanning for a new downlink channel.

The backoff windows are always expressed in terms of powers of two. Suppose the backoff window at a certain time for an SS is 0 to 15 (0 to 2^4 - 1) and the random number picked is 8. The SS has to defer a total of 8 Initial Ranging Intervals before transmitting the RNG-REQ packet. This may require the SS to defer IR intervals over multiple frames. In case a collision is detected, the backoff window is doubled. Now a random number is picked between 0 and 31 and the deferring is continued. This procedure can be repeated for a maximum of 16 times after which the uplink channel is marked as unusable.

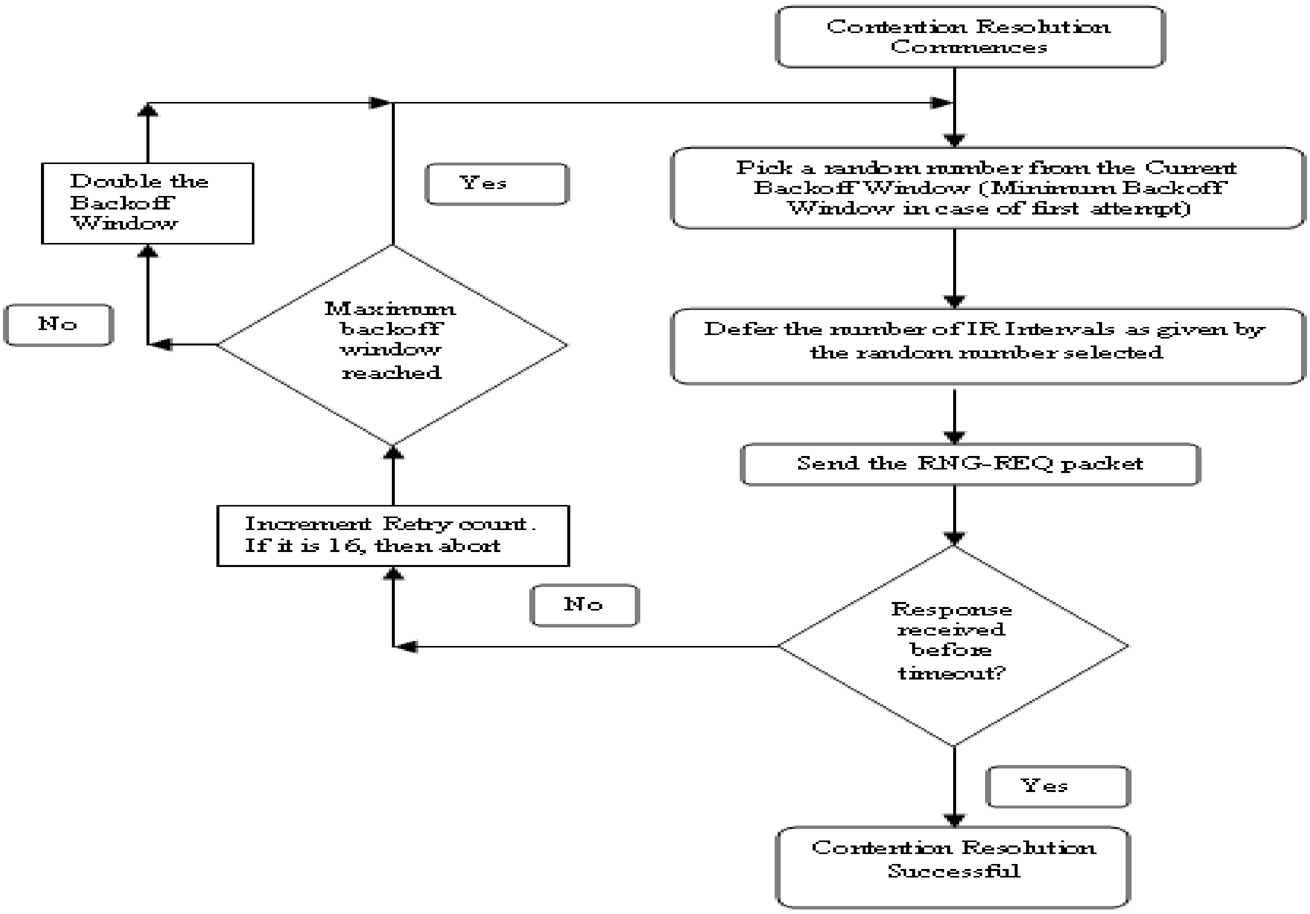
EVALUATION AND ENHANCEMENT OF INITIAL RANGING: DELAY AND SUCCESS-RATIO

In this section we analyze the IR scheme and evaluate mathematically the delay involved in the procedure. First we structure the IR mechanism as a set of distinct states with transitions among these states. Then this information is used to model IR as a Markov process. In a Markov process, the probability of the system making a transition to a particular state depends only on the state the system is currently in. Also, in this Markov process, we calculate the delays associated with the transitions between the states. Finally, by making use of the delays and probabilities associated with each of the transitions, we derive a mathematical equation describing the total IR delay. The Markov process is derived for IR in case of OFDMA PHY, since it covers all the steps in the OFDM based procedure as well. In case of the OFDMA PHY, Code Division Multiple Access (CDMA) codes are used instead of the RNG-REQ messages in the first part of the IR procedure.

MODELING IR AS A MARKOV PROCESS

Markov processes provide very flexible, powerful, and efficient means for the description and analysis of dynamic (computer) system properties. Performance and dependability measures can be easily derived. Moreover, Markov processes constitute the fundamental theory underlying the concept of queuing systems. In fact, the notation of queuing systems has been viewed sometimes as a high-level specification technique for (a sub-class of) Markov processes. A stochastic process is defined as a family of random variables $\{X_t: t \in T\}$ where each random variable X_t is indexed by parameter t belonging to T, which is usually called the time parameter if T is a subset of the set of positive real numbers. The set of all possible values of X_t (for each $t \in T$) is known as the state space S of the stochastic process. A large number of stochastic processes belong to the important class of Markov processes. A stochastic process is a Markov process when the future state of the process depends only the current state and not on the history of the system. A Markov process is a memory-less stochastic process.

FIGURE 4: CONTENTION RESOLUTION PROCESS



After analyzing the Initial Ranging procedure, we enumerate the following states as well as transitions needed for modeling the procedure.

State 1: Waiting for UL-MAP. This is also the start state.
State 2: SS is performing Backoff procedure.
State 3: Waiting for an RNG-RSP message from BS.
State 4: Continue
State 5: Success State – Wait for CDMA Allocation IE.
State 6: Abort – Start network entry procedure at a different DL channel
State 7: Waits for RNG-RSP again.
State 8: Proceed to next phase of network entry
State 9: Commence Periodic Ranging

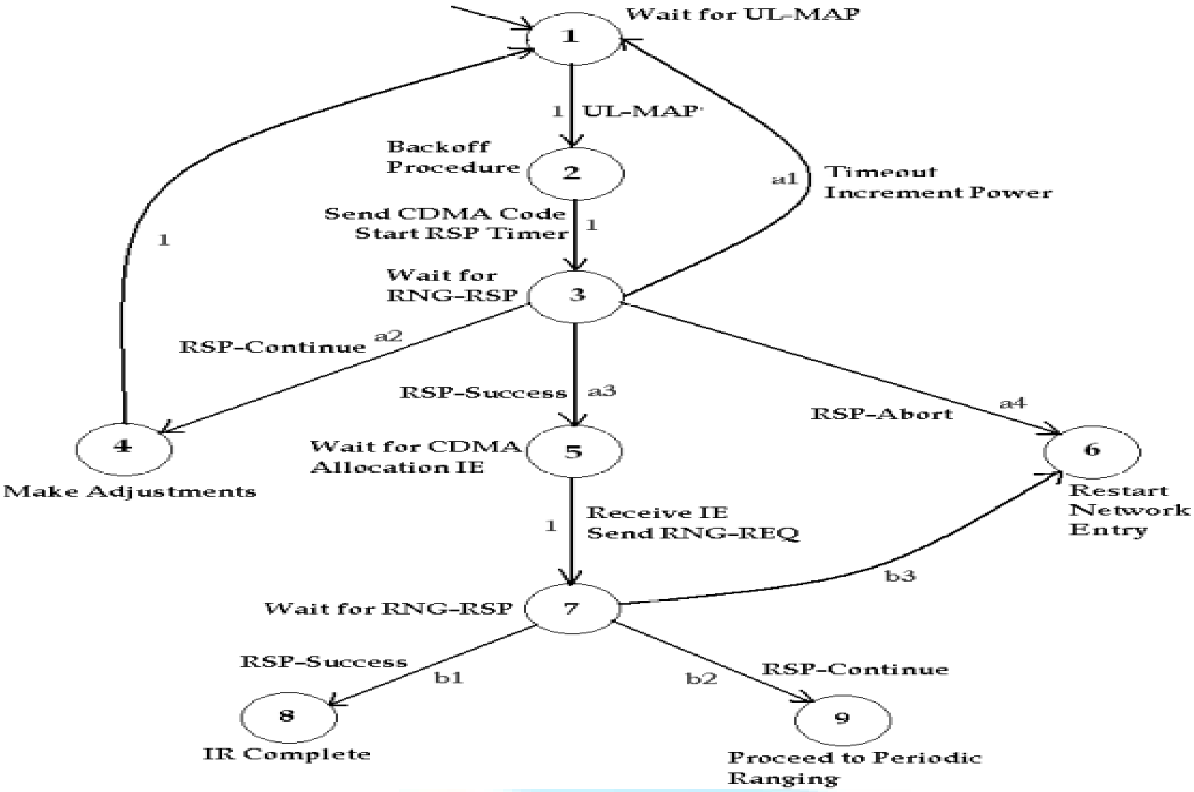
The transitions among the states are as follows. In State 1, the SS waits for a UL-MAP. After receiving this message it makes a transition to State 2. Transmission of CDMA code occurs at end of State 2. Also a timer is set for waiting for RNG-RSP message. This transition leaves the system in State 3. When in State 3, if the timer for RNG-RSP expires then SS increments the power level and goes back to State 1. When in State 3, if RNG – RSP is obtained with Ranging code as well as the Ranging slot, then it makes a transition to State 4. Here the necessary adjustments specified in RNG-RSP are made and system moves to State 1. When in State 3, if RNG-RSP is obtained with success status, then the system transits to State 5. Here it waits for CDMA Allocation IE. After reception it sends RNG-REQ message on the allocated bandwidth and moves to State 7. When in State 7, on reception of RNG-RSP with success status it moves to State 8. On reception of RNG-RSP with continue status it moves to State 9. Else on reception of RNG-RSP with abort status, it goes to State 6 and SS starts the network entry procedure again. When in State 3, if RNG-RSP is obtained with abort status then the system goes to State 6 and SS starts the network entry procedure again. The following matrix diagram shows the transition probability matrix for IR.

TABLE 1: TRANSITION PROBABILITY MATRIX FOR IR

	1	2	3	4	5	6	7	8	9
1	0	1	0	0	0	0	0	0	0
2	0	0	1	0	0	0	0	0	0
3	a1	0	0	a2	a3	a4	0	0	0
4	1	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	1	0	0
6	0	0	0	0	0	1	0	0	0
7	0	0	0	0	0	b3	0	b1	b2
8	0	0	0	0	0	0	0	1	0
9	0	0	0	0	0	0	0	0	1

Using these probabilities we design the Markov process representation of IR as shown in Fig. 3. The states 6, 8 and 9 lead out of IR and are the absorbing states. For these states, transition occurs back to the same state with a probability one. In states 3 and 7, the outgoing probabilities are marked with algebraic symbols a1 to a4 and b1 to b3. This is because the probabilities of the transitions originating from these states are non-deterministic in nature. The sum of probabilities of all transitions originating from states 3 and 6 are still equal to 1. Next, the transition matrix is used to obtain the overall delay formula. For this, we first need to tabulate the delays involved in the individual states.

FIGURE 5: MARKOV MODEL FOR IR SCHEME



The details of the delays involved along with the associated probabilities are given in the table below.

TABLE 2: DELAY COMPONENTS IN IR

Delay Involved	Probabilities
UL-MAP Reception (1 to 2)	1
Backoff Delay + Sending CDMA (2 to 3)	1
RNG-RSP Timeout (3 to 1)	A1
RNG-RSP Reception + Processing (3 to 4, 5 or 6)	A2,a3,a4
IE Allocation Delay +Sending RNG-REQ (5 to 7)	1
RNG-RSP Reception + Processing (7 to 8, 9 or 6)	B1,b2,b3

The numerical values of the delays involved are expresses below:

1. UL-MAP Reception = 5ms (Maximum of one complete frame length) [1 → 2]
2. CDMA Sending Time = Transmission Time = 5ms/2 = 2.5ms [Frame Length/2 (Length of UL subframe) with frame length=5ms] [2 → 3]
3. RNG-RSP Timeout (T3) = 200 milliseconds [3→1]
4. RNG-RSP Reception + Processing (average value)
   = T3/2 + Max. RNG-RSP Processing Time/2
   = 100 ms + 10ms/2 = 105 ms [3 → 4, 5, or 6]
5. CDMA Allocation IE delay = 5s (same as 1) [5→7]
6. Sending RNG-REQ (Same as 2) = 2.5ms [5 → 7]

RNG-RSP Reception + Processing (average value) = 105ms [7 → 8 or 9]

We assume that the delay involved for making changes at SS is negligible compared to the other delays involved.

MATHEMATICAL DERIVATION OF THE BACKOFF DELAY

Consider the first time an SS enters Backoff procedure. Let the Initial Contention window be w_0. The random number will be picked in the range [0, w_0-1]. Let this random number be called k. The SS has to defer a total of k contention slots (CSs). Let the number of CSs in a frame be n_{cs}. The number of frames that have to be deferred is k / n_{cs}. The delay involved here will be (k / n_{cs}) * frame length. After k / n_{cs} frames have passed the SS defers a further k modulo n_{cs} CSs. The delay involved here is equal to (k % n_{cs}) * T_{cs}, where T_{cs} is the length of one CS and % denotes the modulo operation. Therefore the total delay incurred so far is (k / n_{cs}) * frame length + (k % n_{cs}) * T_{cs}. Here the value of k can vary from 0 to w_0-1. Thus, we take an average of the delay over the random number.

AD_0 = (1/w_0) *Sum of [(k/n_{cs})*frame length + (k % n_{cs})*T_{cs}]
as k varies from 0 to w_0-1.

Next we make an assumption that the probability of a successful transmission in a CS is 'p'. Thus, probability of failure will be '1-p'. In case of a failure the contention window is doubled in size. Let the new window be equal to [0, w_1-1]. Similar to previous derivation the delay involved will be

AD_1 = (1/w_1) *Sum of [(k/n_{cs})*frame length + (k% n_{cs})*T_{cs}]
as k varies from 0 to w_1-1. Here w_1 = 2 * w_0.

Again there could be success or failure. So, it will enter the third Backoff window phase [0, w_2-1]. Continuing in this fashion, we get the following delays for the next three phases.

AD_2 = (1/w_2) *Sum of [(k/ n_{cs})*frame length + (k% n_{cs})* T_{cs}]
as k varies from 0 to w_2-1.

AD_3 = (1/w_3) *Sum of [(k/ n_{cs})*frame length + (k% n_{cs})* T_{cs}]
as k varies from 0 to w_3-1.

AD_4 = (1/w_4) *Sum of [(k/ n_{cs})*frame length+ (k% n_{cs})* T_{cs}]
as k varies from 0 to w_4-1.

Here w_2 = 2 * w_1, w_3 = 2 * w_2 and w_4 = 2 * w_3.

We make another assumption at this point. The SS is assumed to complete successful transmission of its CDMA code, in a maximum of 5 Backoff phases. Thus, the worst case of transmission will be four failures followed be a success. The final formula for the delay will be as follows.

Backoff Delay (BD) = $p*\{AD_0 + t/2\} + ((1-p))*p*\{[AD_0 + t] + [AD_1 + t/2]\} + ((1-p)^2)*p*\{[A D_0 + AD_1 +2t] + [AD_2 + t/2]\} + ((1-p)^3)*p*\{[A D_0 + AD_1 + AD_2 + 3t] + [AD_3 + t/2]\} + ((1-p)^4)*p*\{[A D_0 + AD_1 + AD_2 + AD_3 + 4t] + [AD_4 + t/2]\}$

Here t is the time-out after which failure is assumed. So, we take half that value for success i.e. t/2.

MATHEMATICAL DERIVATION OF THE OVERALL IR DELAY

By traversing the transition diagram and multiplying the probabilities with the corresponding delays, the total delay can be calculated. The first part of the delay is in the loops 1-2-3-1 and 1-2-3-4-1. We call this D_{loop}. Then either success or abort occurs which is added to this part to get the final formula.

D_{loop} = 1*UL-MAP + 1*(BD + CDMA sending) + a_1 * (Timeout T3 + D-loop) + a_2 * (RSP + D-loop)

Simplifying we get,

$$D_{loop} = \frac{UL + BD + CDMA\ sending + a_1*T3 + a_2*RSP}{1-(a_1+ a_2)}$$

Now, the total delay involved can be represented using the formula given below.

$D_{total} = D_{loop} + a_3 * (RSP + CDMA\_IE + RNG\text{-}REQ + (b_1+ b_2 + b_3) * RSP) + a_4 * RSP$ (here $b_1 + b_2 + b_3 = 1$)

Substituting the expression for the delay in the loop into the formula for overall delay in IR, we get the following final formula.

$$D_{loop} = \frac{UL + BD + CDMA\ sending + a_1*T3 + a_2*RSP}{1- (a_1 + a_2)} + a_3 * (RSP + CDMA\_IE + RNG\text{-}REQ + RSP) + a_4 * RSP$$

We define the Initial Ranging delay as the time taken by an SS to complete the IR scheme. Therefore, this is the time elapsed from the moment when an SS finds an IR opportunity to the moment when it receives an RNG-RSP message with a success status from the BS. This is done for the purposes of comparing the IR delay before and after the application of circularity. The IR delay process consists of the transmission delays of the request and response messages, the time needed for contention resolution, and the time needed by SS and BS to process the messages received.

Delay = {Time at which RNG-RSP with Success status is received}-{Time at which the first IR opportunity is found}

During IR, multiple SS can send their request messages to the same BS at the same time resulting in a collision. This leads to the contention resolution procedure being restarted with double the size of the backoff window. This leads to an increased IR delay. Thus, the contention resolution phase is the most affected by collisions among packets. We are interested in reducing the time spent by the SSs in competing with each other to send their request messages to the BS. This directly reduces the overall IR delay as well.

The IR success-ratio is defined as the ratio of the number of successfully completed IR procedures of various SSs to the sum of successfully completed IR procedures of various SSs and the number of retransmissions needed to be done as a result of the request packets timing out. This ratio is also directly affected by the collisions between RNG-REQ packets. Success-ratio can be mathematically expressed as shown in the equations below.

$$\text{Success Ratio} = \frac{\text{Successful Attempts}}{\text{Total Number of Attempts}}$$

$$\text{Success Ration} = \frac{\text{RNG-RSP with Success Status}}{\text{RNG-RSP with Success Status} + \text{RNG-REQ Expire}}$$

In the next section we explain the paradigm of circularity that aims to reduce the number of collisions between request packets sent by various SSs. Thereby, it reduces the delay and enhances the Success-ratio of the IR mechanism.

ENHANCEMENT MECHANISM FOR IR

In IEEE 802.16 networks, the IR scheme is used by the SSs in order to acquire the timing offsets and the power adjustments from the BS, so that it can successfully transmit data packets. Although the mechanism is completely defined in the IEEE 802.16 standard, the performance of this mechanism is affected by the collisions between the RNG-REQ packets sent by different SSs. In this section we propose an enhanced mechanism for IR, which incorporates the principle of circularity.

Circularity is a principle that aims to reduce the number of collisions between the request packets in the IR scheme. It is defined as a number that allows us to identify specific groups of events or packets in the network. The number of packets or events in one such group is equal to the circularity value. In each group, one of the packets or events is said to be circularity-satisfied. Here, we introduce certain control measures in case of circularity-satisfied packets and events. By doing this we achieve a decrease in the IR delay as well as an increase in the IR success-ratio. The circularity value is a positive integer. In order to identify the circularity-satisfied packets or events, we keep a count of the number of such packets or events. This count is global in the sense that we do not keep an individual counter for each SS. Whenever the value of this counter is a multiple of the circularity value, the packet or event is said to be circularity satisfied. If the counter is represented by k and the circularity value by c, then the mathematical representation for satisfying circularity is as follows

$k \text{ modulo } c = 0$

The control measures taken are the following. Before sending the first RNG-REQ message or after sending its RNG-REQ packet if the SS does not receive a RNG-RSP message before a timeout, the RNG-REQ is said to have timed out. Then the SS doubles its backoff window and restarts the contention resolution procedure. We keep a count of the number of such expire events. When an 'expire' event is circularity satisfied, the backoff window is double an extra time. By setting the backoff windows, in case of circularity satisfied expire events, the random numbers chosen by the different SSs will have lesser probabilities of being equal. This would mean that the backoff counters of the SSs would also have lesser probabilities of reaching zero at the same instant. Hence, the likelihood of collisions among the request packets decreases. After the requisite number of IR intervals is deferred, the SS is ready to send its RNG-REQ packet. We keep a count of such RNG-REQ packets as well. In the case of circularity satisfied RNG-REQ packets we introduce a certain finite delay before the RNG-REQ packet is sent on the Initial Ranging Interval. Due to the delay introduced a particular request packet is sent a little later than it should have been. So, this sacrifice allows another SS to send its request packet in the meantime.

SIMULATION STUDIES

SIMULATION SETUP

The simulations have been carried out using the Network Simulator 2 (NS-2) which is a discrete event simulator. We have added the WiMAX patch. The simulation script is written in the Tool Command Language (Tcl). The WiMAX control agent is used in the Tcl script in order to produce a detailed account of the activities in the network. The parameters used during the simulations are mentioned in fig 6.

The network configuration used is as follows. A single Base Station is considered. A sink node is considered that is attached through a wired link to the BS. The different values used for the number of Subscriber Stations are 8, 16, 32 and 64. The simulation metrics used are the Initial Ranging delay and success-ratio. The values for these metrics are calculated from the output of the WiMAX control agent. The table in the following page lists the set of important parameters that have been used during the simulation.

TABLE 3: PARAMETERS USED IN NS-2 SIMULATION

Channel Type	WirelessChannel
Radio Propagation Model	TwoRayGround
Network Interface Type	Phy/WirelessPhy/OFDM
MAC Type	802_16
Interface Queue Type	DropTail Priority Queue
Link Layer Type	LL
Antenna Model	OmniAntenna
Maximum Packets in Interface Queue	50
Routing Protocol	DSDV
BS coverage	20 meters
Simulation Time	50 seconds
Number of SS	6 to 54
Traffic Start Time	20
Traffic Stop Time	40

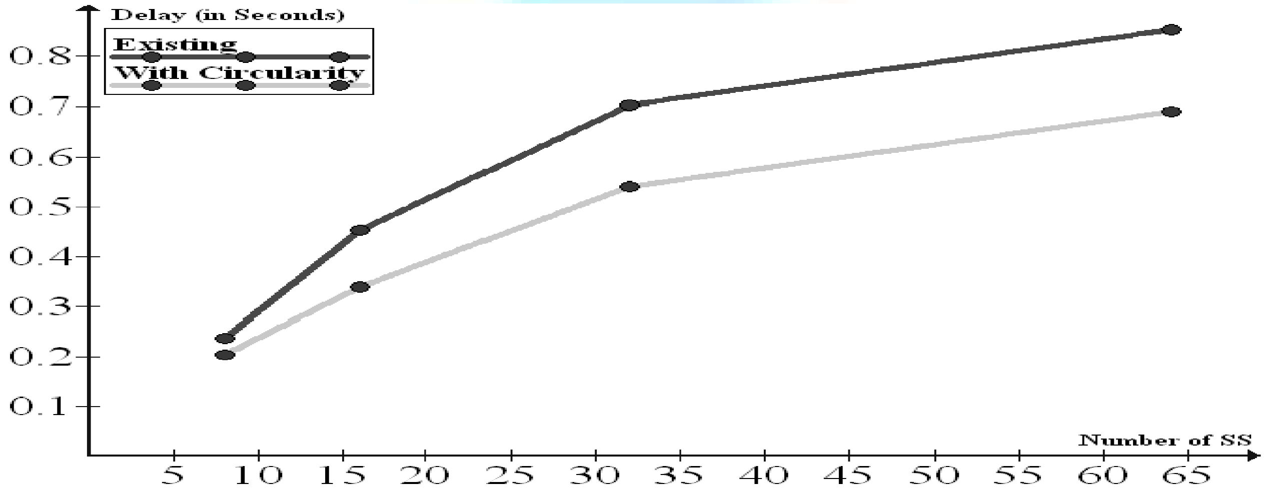
In order to implement circularity the backend files of NS-2, which are written in C++, are modified and the simulations are carried out again.

SIMULATION RESULTS

In this section we present the results of the simulations we have conducted using NS-2. In the first graph (Fig. 6), we compare the delay incurred in the IR mechanism in the existing and enhanced scenarios. The circularity value used in selectively delaying the RNG-REQ packets is 3. The circularity value used in selectively doubling the backoff window an extra time is 5.

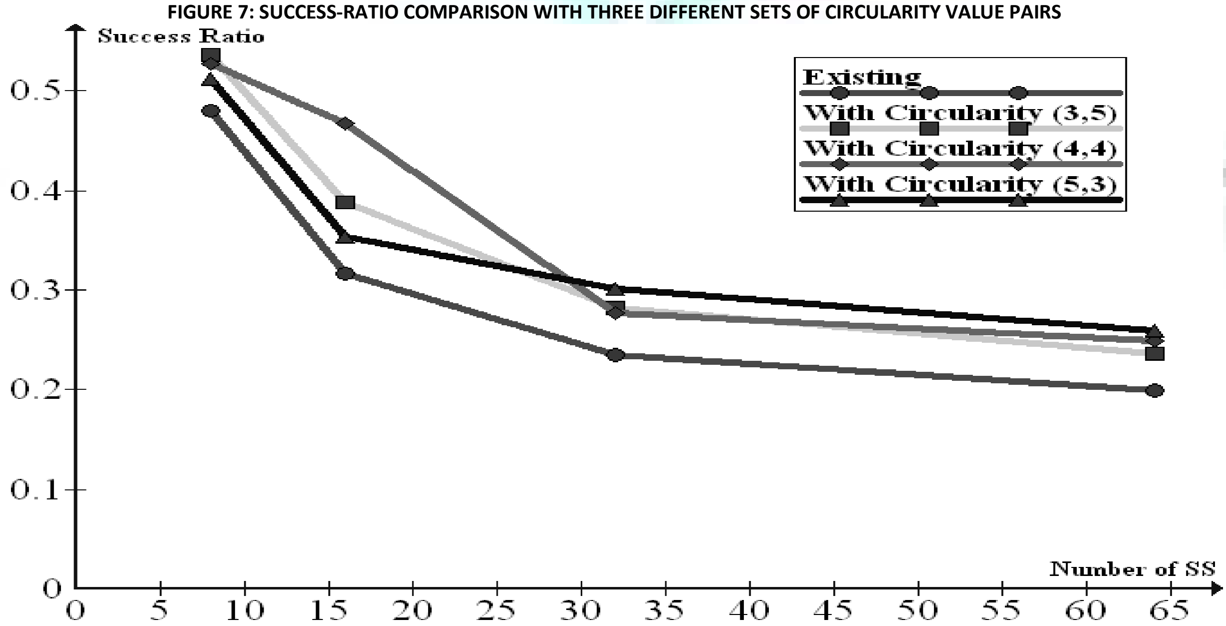
In the second graph (Fig. 7) we plot four sets of values obtained from using four different pairs of circularity values namely (3, 5), (4, 4) and (5, 3). The implementation of Circularity in the IR scheme has decreased the delay incurred and increased the success-ratio. Within the improved scenario we observe the following. Around the 8 node scenario, for small network sizes, the circularity value pair (3, 5) gives higher success-ratio. Around 16 node scenario the circularity value pair (4, 4) gives higher success-ratio. For higher numbers of SSs (32 and 64) the circularity value pair (5, 3) gives higher success-ratio.

FIGURE 6: IR DELAY COMPARISON



From the above observations we can also conclude the following. With increasing number of SS, the circularity value controlling the delay must be increased. This implies that for increasing network sizes, the introduction of delay must be less frequent. With increasing number of SS, the circularity value controlling the window size must be decreased. This implies that for increasing network sizes, the doubling of window size must be more frequent.

FIGURE 7: SUCCESS-RATIO COMPARISON WITH THREE DIFFERENT SETS OF CIRCULARITY VALUE PAIRS



CONCLUSION

IR is an important part of the network entry process. This step allows the SSs to be collocated with the BS. The delay incurred during the mechanism is mainly a function of the delay incurred in the backoff procedure that is at the centre of IR. The concept of a Markov Model Scheme is used in order to analyze the IR mechanism. Due to the collisions among the request packets the performance of the IR mechanism is degraded and leads to an increased time to complete the network entry procedure. The introduction of circularity into this mechanism alleviates this problem leading to reduced delay and increased success-ratio in IR. We have successfully analyzed and obtained a mathematical formula to calculate the delay involved in the IR Scheme. We have also enhances this scheme using circularity, achieving about 25.10% reduction in IR delay.

We have seen the results of minimized uplink access delay, improved throughput and there by reduction in contention slots per frame. Hence circularity principle can be used to enhance the performance of MAC 802.16. We tried to reduce the collisions by using circularity principle comparing with normal the through put is high in circularity. For current design we have assumed the circularity on all SSs.

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